INTEGRATED SUSTAINABLE URBAN WATER NETWORK USING STATISTICAL AND ANALYTICAL HEIRARCHY PROCESS MODELING TECHNIQUE: A CASE STUDY OF SURAT CITY

1. INTRODUCTION:

The conventional Urban Water Cycle incorporates high quality drinking water for all domestic purpose. Moreover large quantity of drinking water is used to transport human excreta. These are also compelling environmental consideration which further plead for redesign of the cycle. Due to population explosion - higher per capita water demand, higher industrial consumption and urbanization chemical load increases on waste water hence providing and receiving environment are often not able to naturally compensate for the huge abstraction and pollution load which sometimes results into severe ecological damage. The ever increasing cost of drinking water treatment and "end of pipe" waste water management are crucial concerned issues today.

The cities are facing a growing pressure for sustainable water services where water is becoming increasingly scarcer. Most urban systems were developed under criteria guided by hygiene and efficient performance goals that are necessarily encompassed with sustainability principle in present scenario. Are the UWS (Urban Water System) sustainable? Answering the question is strategic to plan viable cities in the future.

The provision of safe and universal water supply in an equitable, efficient and sustainable manner is the vision for most of the urban utilities in developing countries. In most developing countries, water as a common pool resource has been in domain of public entities of national and local governments. The public sector model has led to excessive wasteful use of water, poor treatment of water and an unsustainable demand usage pattern resulting in water crisis in urban centers of South –East Asia especially in India.

The planning or reforming urban water sector is the urgent need of the hour for maximizing water beneficial use. The planning is to be driven- based on key postulates of Dublin Environmental and economic principles. The sustainability and conservation of resources are the key drivers of such governance reforms in water management sector. These sector reforms of service arrangement are based on performance criteria, equity efficiency, social, economic and ecological sustainability. (Anand prakash tiwari , 2007)

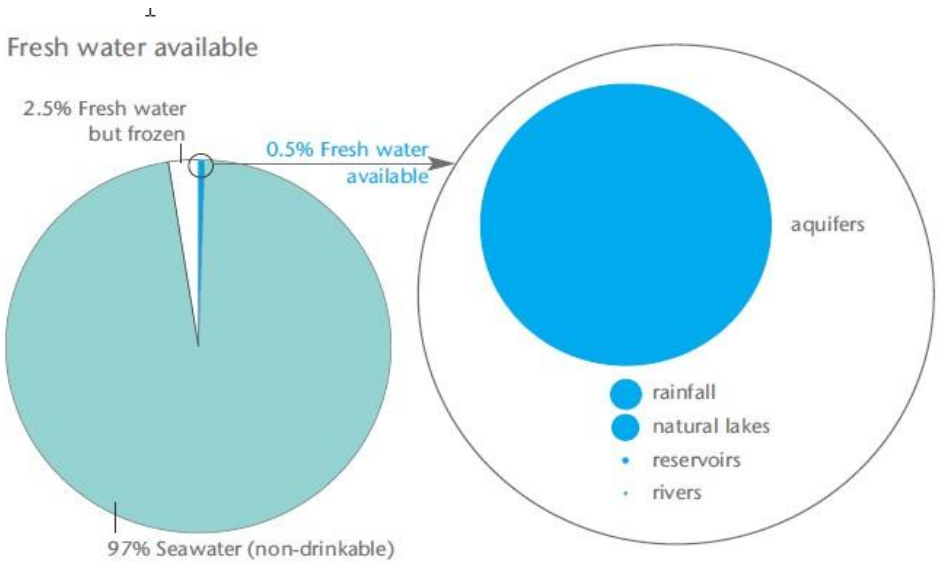
The scientific approach to facilitate decision making in equity, efficiency and sustainability criteria is the main goal for the redesign of urban water network.

2. THE GLOBAL WATER SCENERIO:

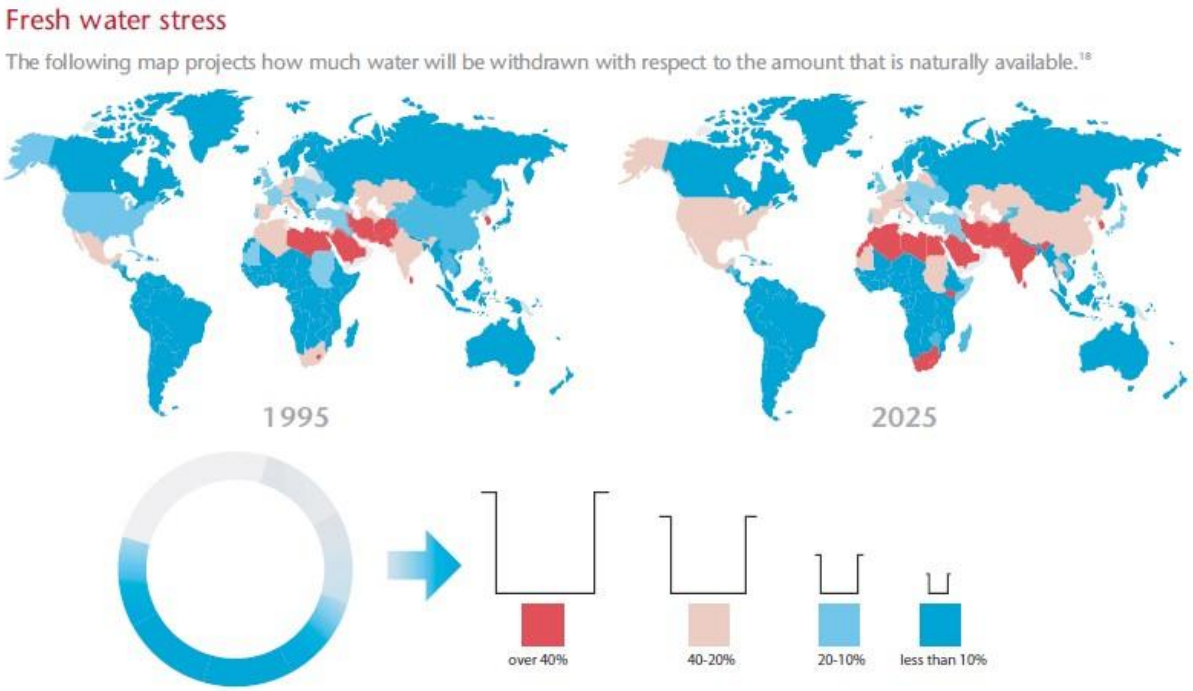
The global water scenario is narrated below:

- Less than 3% of world water is fresh – the rest is seawater and undrinkable.

- Out of this 3% - 2.5% is frozen and locked up in the Antarctica, the Arctic and glaciers hence it is not available to the human beings.
- Thus, humanity must rely on this 0.5% for all man's and ecosystem fresh water needs.

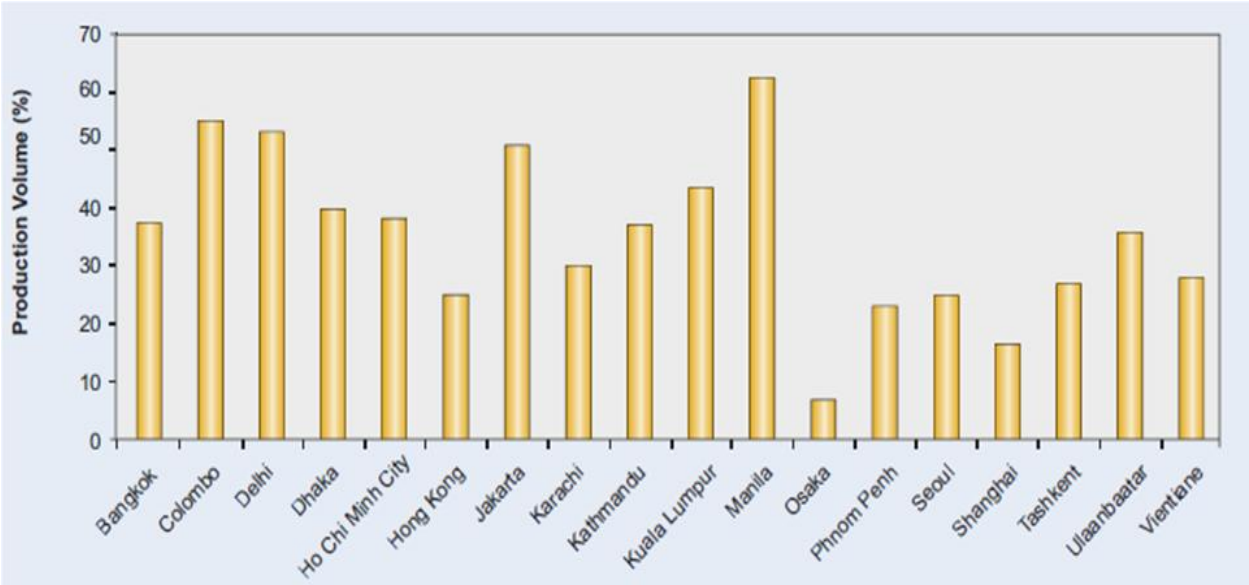


World Business Council for Sustainable Development, August 2005



Vital water graphics, UNEP, www.unep.org

2.1 WATER LOSS SCENERIO IN GLOBAL CONTEXT:



Governments and aid organizations could have a significant impact by tackling the issue of water wasted due to leakages. "One of the major challenges facing Asia, particularly in most urban centres is the large proportion of water loss in distribution networks," (Amy Leung et al,) "By cutting physical losses to half the present level, 150 million people could be supplied with treated water.

Asia loses around 29 billion cubic meters of urban treated water every year, valued at nine billion dollars annually, the ADB estimates. "A key source of water wastage in cities of developing countries in South and Southeast Asia is the high levels of water loss from leaking water pipes and in other parts of the water distribution system," said Tan Cheon Kheong, a research associate at the Institute of Water Policy of the Lee Kuan Yew School of Public Policy at the National University of Singapore. "By fixing water leakages and addressing water pilferage, it is possible for water utilities in the region to cut the amount of water lost".

In Bangladesh, up to 50 percent Dhaka's water is lost due to substandard connections and leaking pipes resulting in supply interruptions during peak demand hours in accordance to the report of Asian Development Bank.

New Delhi in India, a city of some 12 million- faces similar water shortages with long water cuts during summer when demand is high. Data from the Delhi Jal Board - responsible for water supply and treatment in the region indicates that more than half of Delhi's water is wasted because of leakages in the distribution pipeline, theft and poor revenue collection.

2.2 INDIAN SCENERIO:

India	Drinking water coverage estimates					
	Urban (%)		Rural (%)		Total (%)	
	1990	2010	1990	2010	1990	2010
Piped onto premises	49	48	7	12	18	23
Other improved source	39	49	56	78	51	69
Other unimproved	11	3	33	9	28	7
Surface water	1	0	4	1	3	1
Total	100	100	100	100	100	100

WHO/UNICEF JMP, 2012

2.3 STATUS OF WATER SUPPLY IN SURAT CITY:

Description	Old Area	New Area
Area of City	112.27 Sq.Km	326.51Sq.Km.
Total population (As per 2001 census)	24.34 Lacs	28.77 Lacs
Area covered by piped water supply (in %)	95 %	38 %
Population coverage of piped water supply (in %)	97 %	*
Total water supply installed capacity	828 MLD	*
Total average water supplied at present	680 MLD	*
Per Capita Water Supply in lpcd (Net after losses & industrial supply)	148 Lpcd	*
Total Length of Pipelines	2550 Km.	*
Total Nos. of Water Connections: (All size)	3,27,000	*

www.suratmunicipal.org.in, May 2008

* At present- water supply in the extended parts of the Surat city is being catered as per their existing water supply systems and not from SMC water works. After the implementation of new water supply Master Plan, new area will be covered under water supply network.

3. PROBLEM STATEMENT:

Following are some of the issues in Surat city which need attention and in context to these issues the respective study is important.

- Surat city has perennial river Tapi but local government can extract only 692 MLD of water daily from river Tapi according to riparian right which is not sufficient to fulfill the demand of citizen and high growth rate of population. Surat Local government demanding more water extraction capacity from river Tapi with state government since long time but these are all political issues and not yet resolved.

- Due to construction of Weir cum cause way on river Tapi reservoir is formed on upstream side of river which led to stagnation of flowing river water. The stagnation of river water give rise to growth of algae and weeds hence raw water quality get deteriorated which causes problem in intake well as well as in subsequent treatment process. It also reduces the yield of water. Periodical release of water from Ukai dam is required to improve the raw water quality,. Moreover, sewage discharge from some of the area has created terrible impact on river water quality on upstream of river. Also,Sewage discharge enhances the growth of algae, weeds and other vegetation which causes synergestic effect on river water quality.

- Recently, in revised city development plan - it is suggested to lay down pipelines from Ukai to Surat to resolve the issues related to quality and quantity of water demand. Will this decision economically viable or sustainable?

- Due to tidal influences, river water becomes brackish in the downstream of weir in river Tapi. Owing to these problems, the bore water of adjacent area becomes salty and not fit for drinking.

- Over withdrawal of ground water for industrial and irrigation purpose has depleted the ground water table and degraded the quality of ground water too.

- Due to increase in city limit, coverage of water supply network in area and access to water supply to population decreases drastically. Moreover, the actual water supply is only 2 to3 hours/day in Surat city. Rain water harvesting/recharging facilities are available in very little area. Water meter are installed only 0.41% total area of city. Water losses are not measured accurately but approximately 20-30% loss of total water supply is reported according to SMC officer. Approximately 400-450 service complaints are registered every year and approximately 200-250 flood prone areas are in the city which needs storm water pipe network. Energy consumption for water supply is maximum 66% of total cost of water supply and that all energy used is of nonrenewable source.

4. STUDY AREA:

Surat is located in the western part of India in South Gujarat region, is a very dynamic city with a fast growth-rate due to immigration from various parts of India. The city of Surat is situated at latitude 21°12'N and longitude 72°52'E on the bank of river Tapi having coastline of Arabian Sea on its West. It is 13 m above the mean sea level. The city is located on the bank of the river Tapi with a walled city at its centre. The city forms an arc of a circle and the bends enclosed by its walls stretching at a distance along the bank. The topography is controlled by the river and is flat in general and the gentle slope is from north-east to south-west.

As per census 2001, the population of Surat urban agglomeration is 2,811,614. The city has seen an unprecedented growth in the last four decades, recording one of the highest growth rates in the country, and 10 fold population rise. The population of the city as per census 2011 was 40 lacs. Present population is 45 lacs. The city is known for its textile trade and diamond cutting and polishing industries. Surat Municipal corporation area is about 326.51 sq.km which was 112 sq.km before extension of city.(July 2006)

In the first phase of research work, "sustainability Index of Urban water system" was found to understand the scenario of water management in Surat city. The Total area (Extended area) of city is taken in consideration for this work. In second phase "Infrastructure Leakage Index" was found. In third phase, for prediction of pipe leakage historic data related to pipe failure were collected from old south-west zone of the city as it is difficult to collect data from whole city and data is not maintained properly in all zone of the Surat Municipal Corporation. It was not physible to take all zones of the Surat Municipal Corporation; hence old South-west zone is selected for collection of pipe leakage data. The leakage data available is in the form of complaint sheet therefore transformation of data is very difficult job.

5. SCOPE OF THE STUDY:

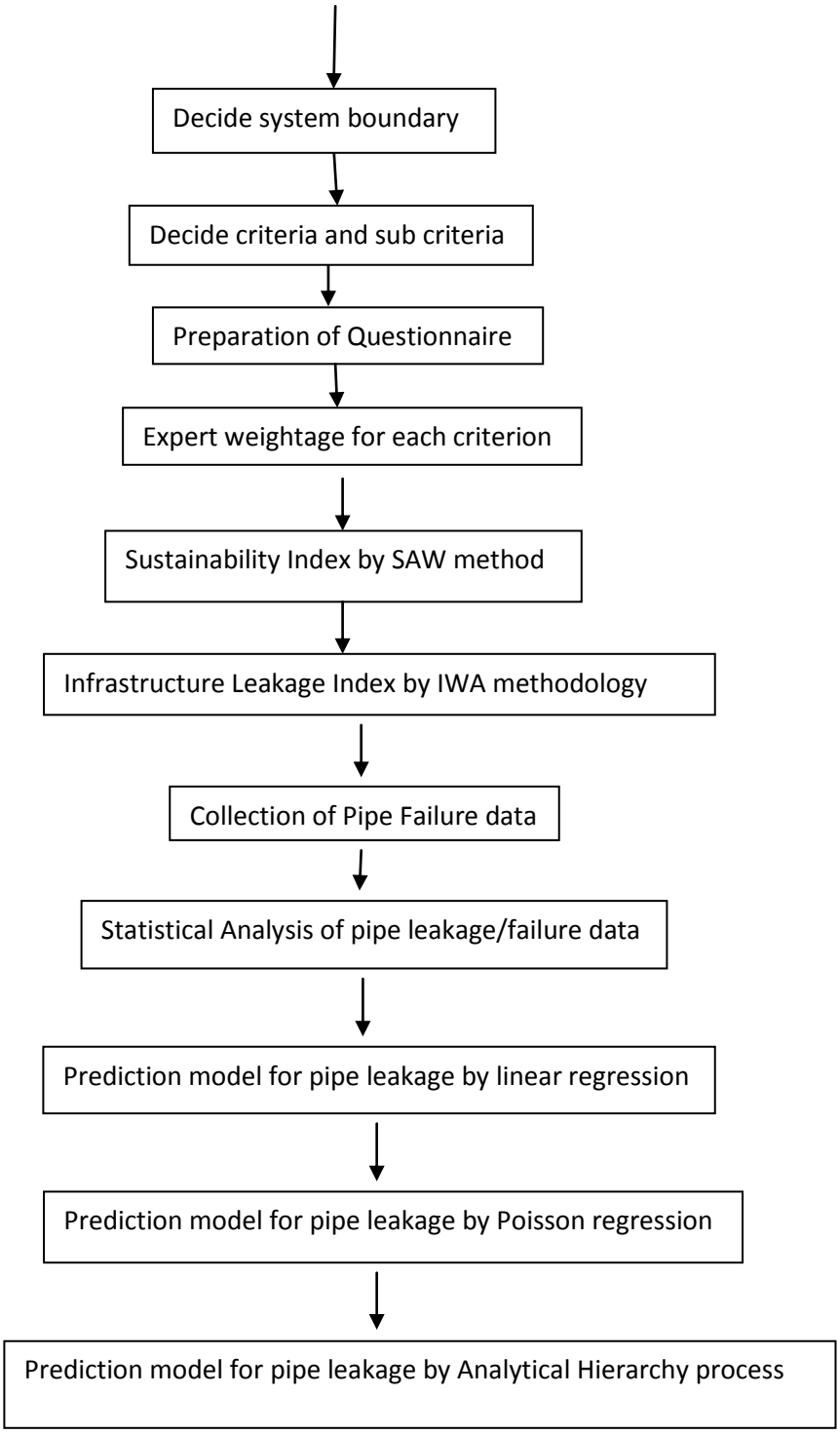
The "Sustainability Index" for area of Surat city (after extension of city limit) is found in the respective research work. The System boundary is decided to decide criteria and sub criteria. Due to unavailability of data during the course of data collection from Surat Municipal Corporation, some important criteria like Depletion of Ground water level were skipped. "Infrastructure Leakage Index" was found by considering total water pipeline network coverage of Surat city area. BENCHLEAK software developed by International Waterworks Association is used for finding Infrastructure Leakage Index.

The historical data were collected from South-west zone of Surat city (year 2005-2010) for prediction of pipe leakage. One of the most critical and tedious job of any pipeline failure program is the collection of reliable data. We tried to have a short but reliable record period which is better than a longer but less reliable period. The pipe leakage data in the south-west part of Surat city (Gujarat) have been collected within the scope of this research work. It contains both map data (depicting location of pipe leakages) and attributed data (describing physical characteristics of each leakage).The data gap was further reduced based on census material, maps and as-built drawing as well as interviews with zone's water department staff. Some of the data were generated based on known data viz. Pressure in pipe network. In south-west zone data's were available in form of complaint sheet. These raw data were collected from South west Zone by taking help of leakage inspector of SMC. The data were converted into finished table form. The clear data before 2005 were not available in SMC record. The analyses were done using dataset after collecting approximately 1000 data from SMC. Firstly statistical analysis was done then linear regression and Poisson regression model were developed. In another stage, for condition assessment of pipe Analytical Hierarchy Process is used.

6. OBJECTIVES OF STUDY:

- To decide the system boundary and study scenario of existing urban water management system for Surat city.
- To identify constraint and problems in existing water management system in the city.
- To study time series change in pattern of urban water supply and management system.
- To develop different models for effective and sustainable urban water network system.
- To evolve effective proposal to make urban water system more sustainable.

7. WORK ORGANISATION OF THE STUDY:


Decide system boundary
Decide criteria and sub criteria
Preparation of Questionnaire
Expert weightage for each criterion
Sustainability Index by SAW method
Infrastructure Leakage Index by IWA methodology
Collection of Pipe Failure data
Statistical Analysis of pipe leakage/failure data
Prediction model for pipe leakage by linear regression
Prediction model for pipe leakage by Poisson regression
Prediction model for pipe leakage by Analytical Hierarchy process

Flow chart describing methodology

8. SUMMARY & RESULT:

The sustainability index was 0.39 which reflects the urban water management system is lacking in its performance. The key findings are unaccounted for water results both from leakage and illegal connections are important and needs due attention to reduce water loss.

Infrastructure Leakage index was found using BENCHLEAK software which is very high (85). Permissible limit for ILI is up to10 as per IWA standard.

To reduce water loss, for pipe network leakage prediction modeling is done using linear regression, Poisson regression and Analytical Hierarchy process. It is found that prediction result obtain by AHP process is more promising than regression model result.

9. LAYOUT OF THESIS:

Chapter 1 (Introduction) gives a statement of problem describing the importance and motivation of the work, the scope and the objectives of the study and also presents organization of the study conducted.

Chapter 2 (Literature Review) presents a survey of literature related to urban water management, sustainability index in water sector, water loss through pipelines and its management, Infrastructure leakage index and different modeling techniques like multiple regression analysis, Poisson regression analysis and AHP method for prediction of pipe leakage.

Chapter 3 (Data collection and Elementary Analysis) This chapter presents general, location, topography, climate, demographic pattern, water supply scenario and water loss scenario of study area in context to global scenario. It provides data requirements and issues related to data acquisition through focuses on description of study region. It provides information about identifying the most influencing factor which affects the pattern and the trend of pipeline leakage.

Chapter 4 (Sustainability Index for Urban water Management system): This chapter presents system boundary and based on that, criteria and sub criteria are decided. Moreover, Questionnaire was prepared, expert views taken and final analysis is conducted by Simple Additive Weightage method.

Chapter 5(Infrastructure Leakage Index for Urban water Management System): This chapter presents different component of water loss and BENCH LEAK software is used for calculation of Infrastructure leakage index of the city.

Chapter 6 (Statistical Data Analysis and Regression Modeling): This chapter focuses on univariate, Bivariate and multivariate statistical analysis. Factor analysis was also conducted to discover underlying determinant factor and recognize the co relationship between different

variables. Two models namely multiple regression and Poisson regression were developed to predict leakage in pipe network.

Chapter 7(Analytical Hierarchy Process Modeling): This chapter presents experts view taken for AHP method and the analysis done by AHP process. Model was developed to access the condition of pipes.

Chapter 8 (Summary, Conclusion and Recommendations for future work): This chapter presents summary and conclusions of the result obtained as well as recommendations were given for future work.

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